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COMPOSTING OF WHEAT STRAW BY USING SHEEP MANURE AND EFECTIVE MICROORGANISMS

KOMPOSTIRANJE PŠENIĆNE SLAME UPOTREBOM OVČJEG GNOJA I EFEKTIVNIH MIKROORGANIZAMA

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ABSTRACT

A research was conducted into the influence of effective microorganisms (EM) and sheep manure on the duration of the process of composting, compost quality and the cost effectiveness of the process. Physical, chemical and biological characteristics of initial material and the prepared compost were analysed. The results of the analysis indicate that 200 days, for how long the process lasted, is not enough to produce a stable and mature compost suitable for use as fertilizer and substrate for production of transplant plants, while the fertilizer obtained by composting straw mixed with sheep manure and inoculated with EM is of the highest quality.

Key words: composting, wheat straw, sheep manure, effective micro-organisms, maturity

SAŽETAK

Obavljeno je istraživanje utjecaja efektivnih mikroorganizama (EM) i ovčjeg gnoja na trajanje procesa kompostiranja, kvalitetu komposta i ekonomsku isplativost postupka. Analizirana su fizikalna, kemijska i biološka svojstva početnog materijala i gotovog komposta. Rezultati analiza pokazuju da je 200 dana, koliko je proces trajao, nedovoljno da bi se dobio stabilan i zreo kompost, pogodan za uporabu kao gnojivo i supstrat za proizvodnju presadnica, a najkvalitetniji je bio onaj dobiven kompostiranjem slame miješane s ovčjim gnojem i inokulirane EM.

Ključne riječi**:** kompostiranje, pšenična slama, ovčji gnoj, efektivni mikroorganizmi, zrelost

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INTRODUCTION

In order to make ecological agricultural production successful, it is necessary to create favourable conditions for quick and unobstructed sprouting of the seed and fast growth of a plant. Favourable conditions include good physical, chemical and biological conditions of the medium for plants to strike root, and can additionally be improved by ploughing harvest residue or by using wheat compost (Parr et al, 1990). However, ploughing large quantities of non-disintegrated harvest residue may have undesirable effects on yield, which can be caused by immobilization of nitrogen in soil, microbiological production or phytotoxic compounds or by transmitting plant diseases and pathogens (Lynch, 1976, Mathur et al, 1993). These undesirable effects can be prevented by composting the material prior to adding it into the soil.

Extensive composting is not profitable due to large loss of carbon and nitrogen, especially when using straw which could be used as food or raw material in paper production. In order to shorten the composting process and reduce the costs, the straw needs to be mixed with manure of high nutritive value and varied population of microorganisms (Raviv, 1998) and/or treated with effective microorganisms (EM) (Mupondi et al, 2006). In addition, it is necessary to monitor majority of chemical and agrobiological parameters of compost maturity in order to select the optimal way to complete the process (Blanco and Almendros, 1997). The process has been completed once the compost is stable and mature. The stability indicates the degree of decomposition of organic matter, and shows the microbiological activity and can be determined respirometrically (Iannotti et al, 1993). Presence or absence of phytotoxic organic compounds, which can limit plant growth, indicate the maturity (Zucconi et al, 1981).

The purpose of this paper is:

1) to evaluate the quality of the compost by measuring several parameters of stability and maturity,
2) to establish the time necessary for composting of the straw inoculated with effective micro-organisms (EM) and a mixture of straw and sheep manure,
3) to determine economic indicators of the profitability of composting.

MATERIALS AND METHODS

The initial material in the composting process was wheat straw and the trial was conducted on three compost stacks on concrete surfaces: straw sprayed with recommended dosage of microbiological preparation Baktomix UN, which is a mixture of active culture of three ground bacteria (*Azobacter chroococcum, Cellulomonas uda i Bacillus megaterium*) (SLEM); straw mixed with sheep manure in the volume ratio 5:1 and inoculated with EM (SLEMOG) and straw mixed with sheep manure (SLOG). The size of the stacks was 10x10x1.5m, and these were humidified until humidity reached 70%. Usage of this preparation improves decomposition of cellulose and increases binding of atmospheric nitrogen.

The composting process lasted for 200 days and the temperature of the compost stacks was measured every day at the depth of 60 cm, as was the environmental temperature until the two were equal. The stacks were stirred every 7 days up until the 70^{th} day of the process. Physical, chemical and biological characteristics of the compost were analysed. The dry matter content was measured by drying 100 g of the fresh matter in a dryer at 75°C until it reached the constant mass (Thomson 2001). The total content of ash and organic matter was measured by performing a calcinations process in a calcinations oven at 550°C during a two day period (Thomson 2001) and the samples of dry matter were used in the process. Electrochemical measurement of compost pH reaction was conducted in a filtrate of 10 g of fresh sample mixed in 100 ml of deionised water for one hour in an agitator (Tiquia and Tam, 2000). Electrical conductivity was measured by conductometer in an extract prepared with 20 g of fresh sample agitated in 100 ml of deionised water for one hour on a rotating agitator (Tiquia and Tam, 2000). The total amount of nitrogen was measured by Kjeldahl method, while mineral nitrogen was measured using the method EN 13652 (Moldes et al, 2007). Ammonia nitrogen was measured by distilling 10 g of fresh sample mixed with magnesium oxide. The sample was distilled into a mixture of 2% boric acid and indicator and titrated 0.005 mol l^{-1} H_2SO_4. Nitrate nitrogen in the rest of the sample was measured by adding Devard alloy, distilling and titrating in the same way as ammonia nitrogen. The total carbon was determined by destruction of a 50 ml dry sample using wet method (ISO, 1998). The CN ratio was calculated out of the ratio of total amount of carbon and of nitrogen. By measuring the quantity of isolated CO_2 in the pattern with NaOH biological characteristics also include respiration intensity. The samples used were fresh samples weighing 25 g that had been incubated at 34°C (Thomson 2001). The aptitude test for growing transplant plants was conducted by sowing cucumber seeds into Styrofoam containers. The plants were grown at a temperature of 27°C with 14-hour daylight until the first leaves appeared (Thomson, 2001) and were then cut just above the ground and their height was measured. The relative vigour of the seed (%) was calculated as a difference between the well developed plants (with properly developed cotyledons) per each treatment in comparison with the control treatment.

RESULTS AND DISCUSSION

Temperature

Temperature monitoring is extremely important, because it influences the flow of certain processes (decomposition of organic matter and destruction of pathogen microorganisms and weed seed).

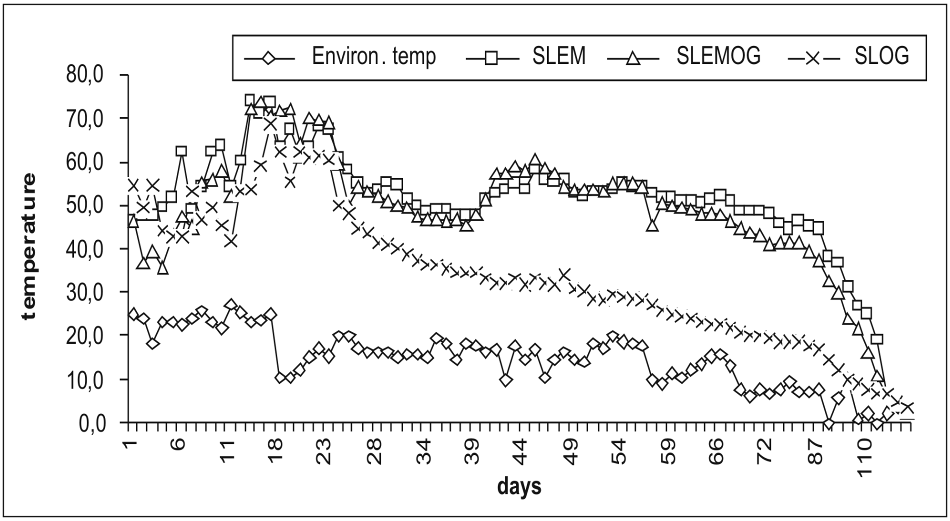


Figure 1: Temperature movement as per compost stack (^{O}C)

The material went through all three temperature phases (heating phase, thermophile phase, and cooling phase). The highest temperature recorded in SLEM treatment was 74.1°C and was recorded on the 13th day, in SLEMOG 73.7°C recorded on the 14th day and in SLOG 68.8°C recorded on the 15th day (figure 1). Haug (1980) and Epstein (1997) wrote about the need to keep the temperature above 55°C for at least three days, that is at least several days. The temperature in the given treatments was over 55°C for 12, 10 and 8 days respectively; which is enough for disinfection of the material. Rynk et al (1992) claim that only three days are necessary in order to destroy pathogen microorganisms, but in order to destroy the weed seed the temperature should not go below 63°C during 3 days. In the SLEM and SLEMOG compost stacks the temperature was above 63°C for several days, but in the third stack (SLOG) only for one day, which indicates a strong influence of EM inoculation on the intensity and duration of the temperature. Temperature of the material and environment equalised after 120 days in SLEM and SLEMOG treatments and after 100 days in the SLOG treatment stack.

Physical, biological and chemical characteristics

Composting is a process in which a complex organic matter is microbiologically disintegrated into simpler compounds, and the increase of dry matter content and ash as well as the decreas of the organic matter content is expected.

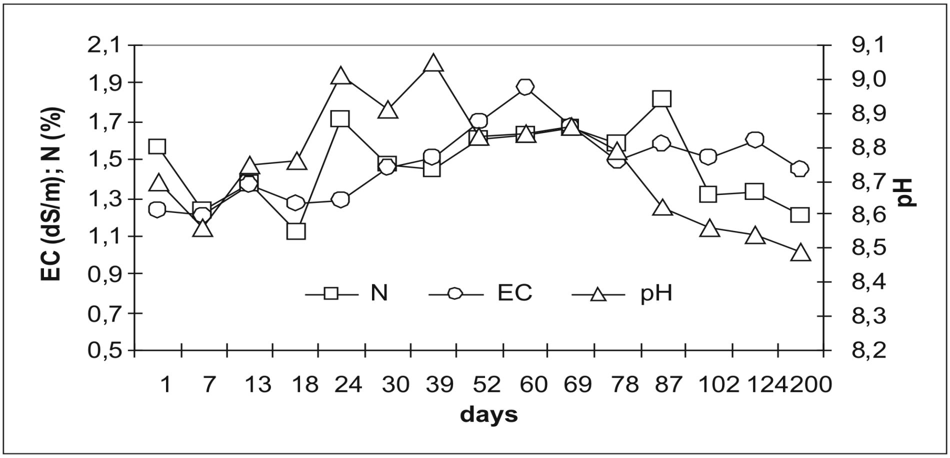
Table 1: Physical and biological characteristics of the initial material and prepared compost

Chemical analysis	SLEM (straw + EM)			SLEMOG (straw + EM + sheep manure)			SLOG (straw + sheep manure)		
	initial	end active	final	initial	end active	final	initial	end active	final
Dry matter	22.78	42.45	37.99	23.58	34.02	33.08	22.81	39.30	36.47
Ash (%)	6,66	48,92	60,09	25,13	53,51	59,90	15,90	60,87	67,66
Org. matter (%)	93.34	51.08	39.91	74.87	46.49	40.10	84.10	39.13	32.34
Respiration**			3.91 b			2.09 a			2.21 a
Vigor (%)			62.07 a			80.00 b			80.65 b

** mg CO_2-Cg^{-1} DM day^{-1}

By the end of the active phase the dry matter content increased from 22.78, 23.58 and 22.81% to 42.45, 34.02 i 39.30 respectively, but did not increase any further (table 1). The reason for that was that the composting was done in the open, where the stacks were exposed to atmospheric influences (in the period from December to March the precipitation was 232.8 mm which is about 30% above the annual average value). The ash content increased statistically significantly in the active phase ($P<0.001$), while the organic matter content decreased. The increase and the decrease were not so significant in the maturing phase. Contreras-Ramos et al (2004) obtained similar results by composting wheat straw with bovine manure. Zmora-Nahum et al (2007) analysed 37 commercial composts obtained out of various materials and from three countries and state that the organic matter content in the composts produced out of wheat amounted to about 45%, although the results varied depending on the country of production (23.7-58%).

Figure 2: Changes in pH, EC and N content as indicators of maturity

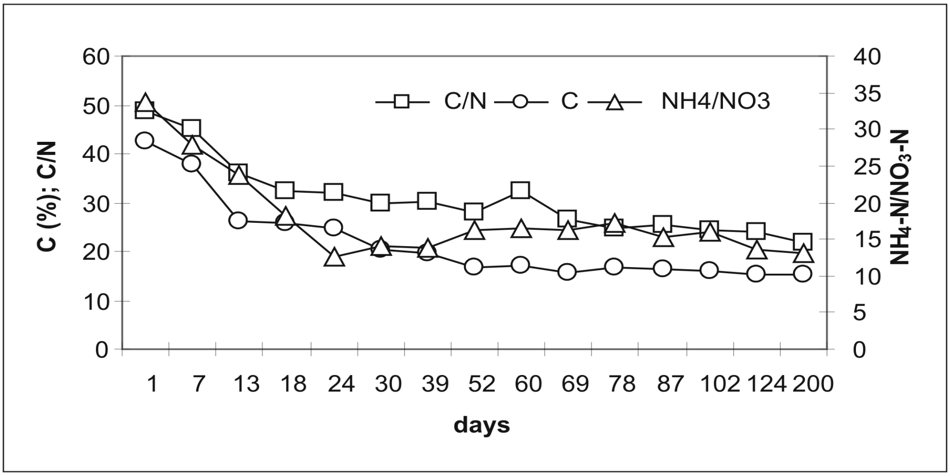


The quantity of the isolated CO_2 is an indicator of the biological activity of the compost (Thompson, 2001), since micro-organisms breathe more intensively, use up more oxygen and isolate more CO_2 in unstable compost (Lončarić et al, 2005). According to Thompson (2001) the composting process lasts until the quantity of the isolated CO_2 is equal to <1 mg g^{-1}ST day^{-1}. After 200 days the respiration was still intensive in the SLEM stack, while its intensity in the other two compost stacks was twice as low (table 1). EM inoculation did not have a significant influence on the respiration intensity (P<0.05).

Relative vigour of the seed shows phytotoxicity of the compost. Thomson (2001) stated the limiting values, according to which the vigour under 85% indicated the immaturity of the compost. Vigour in all the compost stacks was below 85% while the EM inoculation had no significant influence (P<0.05).

pH influences various characteristics of compost, including the availability of nutrient and toxic matters and the microbiological activity (Lončarić et al, 2005.). Average values of pH of the compost stacks reached maximum on the 39th day, after which they were decreasing without sudden changes (figure 2). Guerra-Rodrigeus et al. (2000) obtained the same results (8.5) by composting barley waste and chicken manure, and so did Szanto et al (2007) by composting pig manure rich in straw. pH values of the compost treatments amounted to 8.78 (a), 8.87 (b) and 8.71 (a) which shows that the EM inoculation (microbiological activity and separation of NH_3) had no influence on the change of pH, but the mixture of EM and sheep manure had a significant influence (P<0.01). Muponia et al. (2006) did not establish a significant influence of EM on the changes in pH either.

Figure 3: Changes in C, CN ratio and NH_4^+/NO_3^- as indicators of maturity



Electrical conductivity (EC) is an indicator of the change in the salt concentration in compost, and high concentrations mean better nutrients (especially potassium, calcium and magnesium) content, but if they are too high they decrease water accessibility (Lončarić, 2005). EC of specific composting treatments was 1.31 (b), 1.89 (c) and 1.21 (a), which indicates a significant influence ($P<0.01$) of EM inoculation. Zmora-Nahum et al (2007) listed somewhat higher average values of EC of mature compost obtained out of wheat and manure (3.40), so there was no danger of phytotoxic effect of the composts examined in this trial.

In combination with other parameters, such as respiration intensity, self-heating, pH and density (Thomson, 2001), CN ratio is used as an indicator of compost maturity (Epstein, 1997). Epstein (1997) considers compost with CN ratio < 20 to be stable, while Bernal et al (1998) consider it stable with CN ratio < 12. Average CH fell from 42.55 to 15.19 (figure 3), and this decrease is statistically very significant ($P<0.001$). The most significant decrease of CN ratio was during the first 30 days. Looking at compost stacks the CN ratio at the end of the maturing phase was 25.9 (b), 19.4 (a) and 19.9 (a), which indicates that EM inoculation had no significant influence on that parameter, but adding the sheep manure resulted in a significantly lower CN ratio ($P<0.001$). Similar results about the influence of EM on CN ratio were also stated by Mupondi et al. (2006). NH_4^+/NO_3^- ratio is considered to be a good indicator of the compost maturity, since the quantity of ammonia nitrogen is constantly decreasing and that of nitrate nitrogen constantly increasing. Bernal et al. (1998) claim that the mature compost should have the NH_4^+/NO_3^- ratio below 0.16. The average value in the beginning of composting amounted to 33.8 but decreased significantly during the process to reach 13 ($P<0.01$). The most significant decrease occurred during the first 30 days, while the decrease after that was not so significant, which might be a consequence of low airiness. The ratio of ammonia and nitrate nitrogen was not significantly different in the examined substrates (16.09, 15.44, 18.86), which means that EM inoculation had no influence on the decrease of NH_4^+/NO_3^- ratio.

Economic indicators

On the basis of the cost-benefit analysis of compost production (table 2), it can be concluded that the three varieties of compost production have different economic effectiveness. Composting with added sheep manure (SLEMOG and SLOG) is economically more effective than composting without organic manure (SLEM). SLOG shows better economic indicators than SLEMOG because it has two times lower production costs and cost price. SLEMOG should compensate for the higher costs and cost price (493 kn in comparison to 220 kn/t) with higher quality and possibly wider possibilities for usage (usage for various substrates).

Table 2: Economic indicators of the compost production

	SLEM	SLEMOG	SLOG
Total yield (t)	4,20	6,62	5,96
Total cost (kn)	3358	3267	1315
Cost price (kn t^{1})	799	493	220
Point of covering the costs* (t)	3,73	3,63	1,46

*calculated according to market prices of compost (700 to 1100 kn t^{-1})

CONCLUSION

Based on the analysis of certain physical, chemical and biological characteristics of compost obtained by composting wheat by using EM and sheep manure, it can be concluded that the compost, after 200 days, is not yet mature and stable. The following parameters support this conclusion: respiration intensity >2 mg g^{-1}ST day^{-1} indicates rather high microbiological activity and unstableness of the compost; low relative seed vigour (<85%) indicates presence of certain phytotoxic compounds, high pH and unfavourable ratio of ammonia and nitrate nitrogen indicate high NH_4^+ content; CN ratio above 15 disturbs microbiological balance of the ground so it is less favourable for using. The material went through a long period of high temperatures and it is assumed that pathogen microorganisms were destroyed, but possibly the weed seed was not.

After 200 days compost can be used as organic fertilizer, but not as substrate for production of transplant plants. It was not observed that EM had any effect on the shortening of the time for composting, but the highest quality compost was obtained with mixture of EM and sheep manure.

It can also be concluded that the production of compost from wheat and manure is economically justified as it adds value to the economy (lower cost price than other compost products on the market) while at the same time it disposes of the by-products of agricultural production.

REFERENCES

1. Bernal, M.P., Paredes, C., Sanchez-Monedero, M.A., Cegarra, J. 1998. Maturity and stability parameters of composts prepared with a wide range of organic wastes. Biores.Technol. 63:91-99.
2. Blanco, M.J., Almendros, G. 1997. Chemical transformation, phytotoxicity and nutrient availability in progressive composting stages of wheat straw, Plant and Soil 196:15-25.
3. Contreras-Ramos, S.M., Alvares-Bernal, SD., Trujillo-Tapia, N., Dendooven, L. 2004. Composting of tannery effluent with cow manure and wheat straw. Bioresource Technology 94: 1584-1591.
4. Epstein, E. 1997. The science of composting. Technomic Publishing Company. Lancaster, Pennsylvania.
5. Guerra-Rodriguez, E., Vazquez, M., Diaz-Ravina, M. 2000. Co-composting of barley wastes and solid poultry manure, Biores.Technol. 75:223-225.
6. Haug, R.T. 1993. The Principal Handbook of Compost Engineering, Lewis Publishers
7. Iannotti, D.A., Pang, T., Toth, B.L., Elwell, D.L., Keener, H.M., Hoitink, H.A.J. 1993. A quantitative respirometric method for monitoring compost stability. Comp. Sci. & Utili., 1:52-65.
8. Lončarić, Z., Engler, M., Karalić, K., Bukvić, G., Lončarić, R., Kralik, D. 2005. Ocjena kvalitete vermikompostiranog goveđeg stajskog gnoja. Poljoprivreda, 11(1):57-63.
9. Lynch, J.M. 1976. Product of soil microorganisms in relation to plant growth. Crit. Rev. Microbiol. 67-107.

10. Mathur, S.P., Owen, G., Dinel, H., Schnitzer, M. 1993. Determination of compost biomaturity. I. Literture review. Biol.Agric. Hortic. 10: 65-85.
11. Moldes, A., Cendon, Y., Barral, M.T. 2007. Evaluation of municipal solid waste compost as a plant growing media component, by applying mixture design. Biores. Technol. 98:3069-3075.
12. Mupondi, L.T., Mnkeni, P.N.S., Brutsch, M.O. 2006. The Effect of Goat Manure, Sewage Sludge And Effective Microorganisms on the Composting of Pine Bark, Comp. Sci. & Utili., 3:201-210.
13. Parr, J.F., Stewart, B.A., Hornick, S.B., Singh, R.P. (1990): Improving the sustainability of dryland farming system, a global perspective. Adv. Soil Sci. 13:1-272. Springer-Verlag, New York.
14. Raviv, M. 1998. Horticultural uses of composted materials. Invited lecture. Cta Hort. 469:225-234.
15. Rynk, R., van de Kamp, M., Willson, G.B., Singley, M.E., Richard, T.L., Kolega, J.J., Gouin, F.R., Laliberty Jr. L., Kay, D., Murphy, D.W., Hoitink,H.A.J., Brinton, W.F. 1992. On farm conposting. Northeast Regional Agriculture and Engineering Service, Ithaca.
16. Szanto, G.L., Hamelers, H.V.M., Rulkens, W.H., Veeken, A.H.M. 2007. NH_3, N_{2O} and CH_4 emissions during passively aerated composting of straw-rich pig manure, Biores.Technol. 98:2659-2670.
17. Thompson, W.H. (ed.) 2001. Test Methods for the Examination of Composting and Compost. The United States Composting Council Research and Education Foundation. The United States Department of Agriculture.
18. Wang P., Changa, C.M., Watson, M.E., Dick, W.A., Chen, Y., Hoitihk, H.A.J. 2004. Maturity indices for composted dairy and pig manures. Soil Biology & Biochemistry 36: 767-776.
19. Zmora-Nahum S., Hadar Y., Chen Y. 2007. Physico-chemical properties of commercial composts varying in their source materials and contry of origin. Soil Biology & Biochemistry 39:1263-1276.
20. Zucconi F., Pera A., Forte M., de Bertoldi M. 1981. Evaluation toxsicity of immature compost. BioCycle 22:54-57.

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